New Jersey

Agricultural Experiment Stations

BULLETIN 328

Sprayed Unsprayed

Effect of proper spraying

SOME IMPORTANT ORCHARD PLANT LICE

New Brunswick, N. J.

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NEW JERSEY STATE AGRICULTURAL COLLEGE
DIVISION OF EXTENSION IN AGRICULTURE AND HOME ECONOMICS
ORGANIZED 1914

CONTENTS

ILLUSTRATIONS

New Jersey Agricultural Experiment Stations

BULLETIN 328

FEBRUARY 15, 1918

Some Important Orchard Plant Lice

BY

THOMAS J. HEADLEE, PH.D.

In winter, small (1/50 of an inch long) shining-black oval eggs on the roughened places or close to the buds of the small tender twigs of the apple tree; in spring and early summer, small variously colored lice congregated on the under-sides of the leaves causing them to curl up, die, and fall off, dwarfing the fruit and sometimes ruining the crop.

INTRODUCTION

Four species of plant lice are usually listed as commonly attacking the foliage and to some extent the fruit of the apple tree. All winter in the egg stage on the smaller branches and twigs of the trees. All hatch from the eggs and develop one or more generations on the tree. All except one—the green apple aphis—migrate from the apple to other plants. All return to the apple either the first or second fall following and lay the over-wintering eggs. The species concerned are the green apple aphis (*Aphis pomi* DeG.), the rosy apple aphis (*Aphis sorbi* Kalt.), the oat aphis (*Siphocoryne avenæ* Fab.) and the clover aphis (*Aphis bakeri* Cowsen).

In New Jersey the clover aphis has not been recorded. Until two years ago the green apple aphis was the only species regarded as a pest. In the season of 1915 the rosy apple aphis appeared in large numbers in almost all parts of the state and

did much damage. The failure of the usual methods of aphis control when this species appeared necessitated a study of the problem, and in the following account it is attempted to set forth the most important of the results obtained.

RECOGNITION MARKS

The stage in which the aphis is found throughout the winter and early spring is a small shining-black egg fastened to the bark of the twigs and smaller branches. They are likely to be laid on the tender ends of water sprouts, in the depressions about bud and pruning scars, or partly or completely inserted between the buds and the stem. The eggs of green apple aphis have in our experience been more commonly found on the water sprouts than those of either of the other species.

Fig. 1. First stage of the green, the rosy and the oat aphis
(After Parrott, Hodgkiss and Lathrop)

The newly-hatched lice of the green, the rosy, and the oat aphis are very small, dark-green in color and look much alike. Parrott, Hodgekiss, and Lathrop[1] have discovered differences by which one species may be told from another, and Dr. Alvah Peterson has found that the characters cited by them hold for New Jersey conditions.

The length of the antennæ, or feelers, and the size and shape of the cornicles, or honey tubes, are the points that we have found most useful in distinguishing the different species.

As these young develop into wingless stem-mothers, their characteristic differences become so distinct that recognition of

[1] Parrott, P. J., Hodgekiss, H. E., and Lathrop, F. H., 1917. Plant lice injurious to apple orchards. II. Studies on control of newly-hatched aphides. N. Y. (Geneva) Agr. Exp. Sta. Bul. 431.

Table of Distinguishing Characters

Species	Color	Head	Antennæ	Body	Honey tubes	Legs
Oat aphis	Extremely dark green	Two blackish rectangles	Short, reaching backward only to the middle pair of legs	Not powdery	Black, mere disks	Very dark
Green apple aphis	Dark green and lighter than the other species, varying to almost a brownish yellow	Dusky and rather brownish	Longer than the first and shorter than the second; blackened at tip	Slightly powdery	Short, conical	Dark tipped
Rosy apple aphis	Dark green	Dark with a pair of darker areas	Long, reaching almost to base of honey tube	Decidedly powdery; several rows of black tuberculate spots running lengthwise	Long, with expanded outer ends	Dark

the species becomes easy. The adult stem-mother of the oat aphis is pale yellowish green, with a darker streak along the middle line of the back, while that of the green apple aphis is bright green, and that of the rosy aphis has a slaty cast and is covered with powder.

NATURE AND EXTENT OF INJURY

As soon as each species hatches from the egg it attacks such of the young unfolding foliage as may be out. It works its mouth parts through the rind of the plant and sucks out the sap. As the flower buds are exposed by the development of the tree, they in turn are attacked.

Fig. 2. Injury to foliage

The wounding of the tissue and the withdrawal of sap upsets the rate of growth of the part attacked in such a fashion as to cause curling of foliage and distortion of the fruit.

The activity of the oat aphis causes little curling of the foliage, and as the second brood develops wings and leaves the tree by the time the fruit has well set, the trouble is soon past. To what extent the feeding on the buds and flower clusters may so weaken them as to prevent setting, we do not know, but it is possible that such an injury takes place.

The green apple aphis, like the preceding species, causes little curling of the foliage at the beginning of the season. Later its activity results in the most pronounced curling.

The rosy apple aphis, on the other hand, produces much curling of the foliage, probably because it devotes its attention more exclusively to the leaves.

Both the green apple aphis and the rosy, especially the latter, have done very serious injury to fruit, causing it to be knotted and gnarled and never to reach a salable size.

Recently it has been shown that plant lice can and do spread fire blight.[2] It is thought that such of them as hatch from eggs which were laid in blight cankers may carry the blight germ to other parts of the tree.

Fig. 3. Injury to fruit

The extent of the injury depends upon the abundance of the lice. When very plentiful the tree may be almost defoliated and the crop utterly ruined. In 1915 the injury was general throughout the state and orchards everywhere showed the work of plant lice. The season of 1916 showed a smaller amount of

[2] Merrill, J. H., 1917. Further data on the relation of aphides and fire blight (*Bacillus amylororus*). In Jour. Econ. Ent., v. 10, p. 45–47.

injury, and there was an epidemic of fire blight. As seen by the writer, there is no necessary connection between the epidemic and the aphis, because the aphis was worse in 1915 and 1917 than in 1916, while the fire blight was limited in these two years.

In 1915 Mr. John Barclay, of Cranbury, estimated the damage done his orchard by apple aphis at $40 an acre. This occurred in spite of the practice of what was then thought to be careful spraying for the insects.

LIFE HISTORY AND HABITS

All species pass the winter in the egg stage attached to the bark of the twigs and smaller branches of the trees. The green apple aphis appears to be partial to water sprouts, while the eggs of the other species are likely to be found in depressions about pruning, bud and fruit scars, or thrust almost or quite out of sight between the bud and stem.

The oat aphis was the first species to hatch at New Brunswick and vicinity in the spring of 1917. They were discovered on the buds on March 31. Then (about April 12 to 14) came the rosy aphis and green apple aphis almost coincidently. The difference in the time of hatching of the first two species was sufficiently great for the oat aphis to have hatched and reached the buds, and to have been destroyed by insecticides, while the rosy, at that time in the egg stage, hatched later and seriously damaged the foliage.

The oat aphis reached the buds as they were swelling and before any leaves were yet projecting, while the rosy came on only after the tiny leaves were projecting from forward buds like squirrel ears. The rosy aphis hatched at the same stage of bud development as in 1916. Inasmuch as the experience relative to time when the rosy aphis hatches differs in different parts of the country, the writer will quote from his notes in 1916: "Early in the forenoon Mr. Barclay called me over the telephone and told me that the aphis began emerging in his orchard in enormous numbers on the preceding afternoon (April 15, 1916). The day was clear and warm and the personal examination, which I made later in the morning, showed aphis present everywhere in large numbers. Nearly every flower bud on unsprayed trees showed at least one-half dozen specimens, while the buds on trees treated with 'Scalecide' or with winter-strength lime-sulfur in dormancy rarely exhibited more than one specimen to the bud. * * * At this time the most advanced cluster buds showed the first green leaves separating from the cluster, and the young leaves projecting from the opening buds like squirrel ears were

very common everywhere throughout the orchard." It is thus seen that for two years in the Barclay orchard, the rosy aphis hatched after the leaves began to emerge from the buds and at a time when shelter from spraying materials could be had. The second generation of the oat aphis developes wings and migrates from the apple to various grasses (species of *Poa*). Here they breed throughout the summer. It is thought that they pass the winter on grains and grasses and do not return to the apple until the second fall. At any rate, in the fall (late September or early October) winged forms of this species begin to appear on the apple, males and females are produced, and fertilized eggs are laid on the tree. Egg-laying may continue until December. The species may be found laying eggs on pear, quince, hawthorne, and plum trees.

The third generation of the rosy aphis is winged and migrates from the trees about the middle of June to plantains, where it remains throughout the summer, returning to the apple in late October and early November. Males and females are produced by the returned migrants and fertilized eggs are laid to pass the winter.

The green apple aphis lives on the apple, pear, quince, and hawthorne, especially the first, throughout the summer. The winged forms seem merely to spread the species to other parts of the tree or to other trees. In the fall (October) males and females are produced and fertilized eggs are laid for winter.

When the eggs are first laid they are yellowish in color and gradually become darker until they assume the normal shining black appearance.

It thus appears that the apple suffers from the oat and the rosy aphis during the early stages of fruit production only; the former leaving when the apples are just well set and the other in June. The green aphis, on the other hand, is on the trees continuously throughout the season.

Perhaps the most puzzling phase of the aphis problem is the fact that the plant lice are bad one year and hardly noticeable the next. The explanation for this puzzle appears to lie in the effect of the weather upon the aphids and their natural enemies.

The natural enemies of apple plant lice may be placed in two general groups—the parasitic enemies, which usually lay their eggs inside the body of the aphid, from which comes a grub that eventually destroyes the aphid, and the predaceous enemies, that attack, kill and consume the lice. The principal members of the first group belong to the *Hymenoptera*, or the group of bees, ants and wasps. These parasitic forms are usually very small and very greatly influenced by weather conditions.

The elements of climate which, because of their large variations, influence insect life to a great extent, are temperature and moisture, especially the former. It is therefore, to be expected that if weather has anything to do with the matter, temperature and moisture must be playing a large part. Perhaps the influence of these factors upon the relation existing between the plant lice and their natural enemies has been best illustrated by a study of *Lysiphelbus tritici*, a small hymenopterous (the order which includes the bees, ants and wasps) parasite of *Toxoptera graminum*, one of the most injurious of the plant lice attacking wheat and oats.

Under a constant temperature of 50° F. and an atmospheric moisture ranging from 75 to 100 per cent, 43 days were required for the parasite to develop from egg to adult. Furthermore, at this temperature, the number of healthy young produced is greatly reduced, in fact the insect hardly reproduces itself. On the other hand, under a temperature of 50° F. and the same atmospheric moisture the louse requires 24 days from birth to maturity and reproduces, once that stage has been reached, nearly one young a day for 27 days.

At a temperature of 70° F. the parasite can complete its life cycle in 10 days, and the average number of young ones from a single pair of parents amounts to 56. This means that in one month the offspring of a single pair would be more than 46,000. On the other hand, at a temperature of 70° F. the louse reaches maturity in 9 days and produces in the 11 days following about 29 young. At this rate in one month a single louse would produce less than 14,000 young.

It is thus seen that while with a low temperature the lice can carry on their activities practically unhindered by the parasite, the advent of high temperature is likely to be followed by their destruction by reason of the greater reproductive power of the parasite.

The studies of the effect of moisture are extremely limited, but such evidence as has been collected indicates that so long as the atmosphere is not too dry to prevent the vigor of the food plant and not wet enough to encourage the attack of parasitic fungi, variations in atmospheric moisture have little effect upon either the louse or its parasite.

No studies have been made to show the effect of climate upon the predaceous enemies. The lady-bird beetles and their larvæ are the only important forms that attack the lice under low temperatures and they are only rarely sufficiently abundant to prevent an outbreak.

In summing up the meager knowledge at hand relative to the effect of climatic conditions on the abundance of plant lice, we may say that a late cool spring is likely to show a serious attack of these insects, while an early warm one is likely to show few of them. On the other hand, it is quite possible that a late cool spring might not be accompanied by a plant louse outbreak because of the destructive effect of a late low temperature, or the activity of lady-bird beetles, or still other agencies less well understood.

It is also quite possible that an early warm spring might be accompanied by a plant louse pest by reason of an earlier reduction of the parasite.

Control

Determining Whether Control Measures Are Necessary

In view of the facts just presented showing the uncertainties of aphis outbreak, the first problem of the grower is to determine whether the conditions in his orchard render control measures necessary. If, as spring approaches, the water sprouts, twigs and smaller branches bear no aphis eggs, treatment for lice is unnecessary, for there will not be sufficient migration from adjacent orchards to create an infestation in the first half of the season. If, on the other hand, as spring approaches, aphis eggs are present on the water sprouts, twigs and smaller branches, treatments should be made as a matter of insurance against damage.

The small black eggs are rather inconspicuous and sharp eyes are required to find the first ones. After the grower has become familiar with their appearance he can pick them out without difficulty.

The Problem

When the eggs are present the problem of controlling the various species of apple aphis appears to involve the destruction of the specimens on the trees before they have a chance to do the damage to fruit and foliage. The aphis appears on the trees in the fall (October and November), and eggs laid by them carry over the winter until bud-opening time. The aphis must be attacked just before or during egg-laying in the fall, or while still in the form of the egg resting on the bark of the tree, or in the spring as a nymph that has just hatched.

Destroying the Aphis in the Fall

In the fall the return of the aphis usually covers a considerable period. In the late fall shining black eggs, immature yellowish eggs and adult aphids are found on the same twig. Anything short of several sprayings would seem to be doomed to failure as a method of control.

Destroying the Aphis in the Egg Stage

Throughout the winter and early spring the eggs remain on the tree, open to attack, and this would seem to be the logical time to compass their destruction. Many efforts have been made to find a substance which would destroy the aphis egg, not harm the tree, and sell for a price that would not prohibit its use. It can truthfully be said that up to the present time no such substance has been given to the public.

During the winter and spring of 1917, Dr. Peterson made a preliminary study of the egg and of the effects of certain chemicals upon it. He found that the egg envelope exhibits at least two layers—an outer semi-transparent brittle envelope (glutinous when the egg is first deposited) and an inner pigmented elastic membrane. A third layer may be seen as the nymph hatches, but this is probably the first-cast skin of the nymph. The outer layer appears to exercise a protective function, resisting strains and stresses and retarding evaporation of the body fluids. The fact that this transparent layer encloses the pigmented layer leads one to suspect that, like the jelly on a frog's egg, it may keep the egg warm by transmitting the sun's rays and retaining the heat into which they are transformed by the pigment.

Sometime before hatching, the period ranging from two to thirty days, the outer layer splits along the median line, exposing the pigmented layer, and the egg is thereafter very sensitive to weather (dry air particularly) and insecticides.

In the course of his experiments, Dr. Peterson found that the eggs were strongly affected by carbolic acid and by winter-strength lime-sulfur. He found that the carbolic acid appeared to soften the outer brittle layer in such a fashion that the egg soon shriveled, while the lime-sulfur appeared to harden it and to prevent hatching.

Table 1, taken from Dr. Peterson's work, will serve to show the effect of our common sprays upon the eggs and to indicate some substances worthy of further trial. The table is the summary of a large series of experiments. The percentage killed is

determined on the assumption that only that percentage of the total number would hatch which did hatch in the lots laid aside as checks and not treated with any substance in any way.

Table I

Effect of sprays on aphis eggs

Materials Used	*Proportion Killed Per cent*
Lime-sulfur, 1-8 or 1–9	85–100
Lime-sulfur, 1–8 plus "Black Leaf 40," 1–500	97
"Black Leaf 40," 1–500 plus laundry soap, 2 lb. to 50 gal.	45
Laundry Soap, "Fels Naptha," 2 lb. to 50 gal.	5–33
"Scalecide," 1–15	25–65
"Mechling's Scale Oil," 1–19	79–90
Sodium Sulfocarbonate, 1–19	85
Sodium Chloride, 1 gm.* to 5 cc.** water	26–35
Sodium Hydroxide, 2 pt. to 98 cc. water	85–95
Crude Carbolic Acid (100%), 2 cc. to 98 cc. of solution, plus soap, 2 lb. to 50 gal. water	93–100

* gm.—gram.

** cc.—cubic centimeters.

Several important facts stand out in this table. The deadly quality of lime-sulfur is increased by the addition of 40 per cent nicotine. "Scalecide" is much less effective than lime-sulfur alone. "Scalecide," in which we are assured there is no carbolic acid, is much less effective than "Mechling's Scale Oil," in which, according to the makers, is found a percentage of carbolic acid. The great efficiency of a 2 per cent crude carbolic acid solution to which soap has been added is shown.

In the present stage of knowledge none of the substances can be recommended for the destruction of the eggs during dormancy, but the prospects for the development of such a spray seem encouraging. It can be said, however, that the study points to the idea that an application of the lime-sulfur and tobacco mixture at the green bud stage, even if not all of the eggs have hatched, is likely to give control by reason of the destruction of the unhatched eggs as well as the newly-hatched nymphs.

Destroying the Aphis in the Spring and Summer

In the spring, when first hatched, the young nymphs are very delicate, and, consequently, very susceptible to the effect of spraying mixtures. This led investigators to place reliance on spring and summer spraying as a means of controlling the

species. Unfortunately, several years of experience have demonstrated for the rosy louse, at least, that an attempt to control it after the foliage has been curled is sure to fail, and that an attempt to control it after the buds have really opened is almost certain to fail. The period in the spring when all three species can be brought under control has been thought to be very short, and was thought to extend from the hatching of the egg to the opening of the buds. The problem was further complicated by the fact that the eggs of the rosy aphis hatched, in some cases, coincidently with the opening of the early buds.

TABLE 2

EFFECT OF NICOTINE SPRAYS ON ROSY APHIS

Number of leaves	TREATMENT	Percentage living at end of experiment
2	Water only	100
2	"Black Leaf 40" (1 part) + water (900 parts)	60
2	"Black Leaf 40" (1 part) + water (900 parts) + soap (2 lbs. to 50 gal.)	10
2	"Black Leaf 40" (1 part) + water (700 parts) + soap (2 lbs. to 50 gal.)	1
2	"Black Leaf 40" (1 part) + water (500 parts)	10
2	"Black Leaf 40" (1 part) + water (500 parts) + soap (2 lbs. to 50 gal.)	0

In 1915 Parrott and Hodgkiss[3] recommended the delay of the usual winter-strength lime-sulfur, to which 40 per cent nicotine has been added at the rate of ¾ of a pint to 100 gallons, or about 1 part of nicotine to 1,000 parts of the spraying mixture, and the application of the mixture at the green bud stage. In 1915 one of our best apple growers almost completely failed to obtain control of aphis by adding nicotine to his pink-bud or cluster-cup spray at the rate of 1 to 800, while another claimed perfect control by adding the 40 per cent nicotine to the same spray at the rate of 1 to 500. To discover the strength of nicotine necessary for a complete kill of all ages of the rosy aphis, which has seemed more resistant to spraying solutions than either of the others, the experiment recorded in table 2 was made.

[3] Parrott, P. J., and Hodgkiss, H. E., 1915. Controlling plant lice in apple orchards. N. Y. (Geneva) Agr. Exp. Sta. Bul. 402.

Thus it appears that even when used with soap, which seems to give to it the maximum killing strength for aphis, 1 part of the nicotine to 500 parts of water was required to give a complete kill.

This suggested a number of points that needed clearing up, such as:

1. To what extent in comparison with other treatments does winter-strength lime-sulfur effect a control when applied during dormancy and before the eggs have hatched?
2. To what extent will winter-strength lime-sulfur applied at the green bud stage just after the lice hatch effect a control?
3. To what extent is the combination of winter-strength lime-sulfur and 40 per cent nicotine at the rate of 500 to 1 superior to a combination at the rate of 1,000 to 1?
4. To what extent would a winter-strength lime-sulfur treatment before the lice hatch, followed by an extra treatment of nicotine and soap just after the lice hatch, prove effective? This point was considered because of the fact that in 1915 the hatching of the rosy aphis was thought to have occurred after the buds opened.
5. To what extent would Scalecide (for which claims have been made) serve as a control?

In 1916 experiments were planned to answer these questions. They were located on the farm of Mr. John Barclay, of Cranbury. Mr. Barclay made all the applications according to schedule, and the quality of the spray coatings given by him could not be bettered. The trees were seven years old and very thrifty.

The plan of the experiments follows:

PLAN FOR APHIS EXPERIMENT IN THE APPLE ORCHARD OF MR. JOHN BARCLAY, NEAR CRANBURY, NEW JERSEY

No. 1	No. 2	No. 3	No. 4	No. 5. North	No. 6	No. 7	
x x x	x x x x	x x x x	x x x x	x x x x	x x	x x	{ Fall Pippin ½ / Greening ½
x x x x	x x x x	x x x x	x x x x	x x x x	x x	x x	Duchess
x x x x	x x x x	x x x x	x x x x	x x x x	x x	x x	Grimes
x x x x	x x x x	x x x x	x x x x	x x x x	x x	x x	McIntosh Red
x x x x	x x x x	x x x x	x x x x	x x x x	x x	x x	McIntosh Red
x x x x	x x x x	x x x x	x x x x	x x x x	x x	x x	Rome Beauty
x x x x	x x x x	x x x x	x x x x	x x x x	x x	x x	McIntosh Red
x x x x	x x x x	x x x x	x x x x	x x x x	x x	x x	Twenty Ounce
x x x x	x x x x	x x x x	x x x x	x x x x	x x	x x	Stayman Winesap
x x x x	x x x x	x x x x	x x x x	x x x x	x x	x x	Twenty Ounce
x x x x	x x x x	x x x x	x x x x	x x x x	x x	x x	Jonathan
x x x x	x x x x	x x x x	x x x x	x x x x South	x x	x x	Duchess
Lime-sulfur (1 to 9) during dormancy; "Black leaf 40" (1 to 1,000) + soap (2 lbs. to 50 gal.) when buds showed green	Lime-sulfur (1 to 9) during dormancy; lime-sulfur (1 to 9) + "Black leaf 40" (1 to 1,000) when buds showed green	Lime-sulfur (1 to 9) when the buds showed green	Lime-sulfur (1 to 9) + "Black Leaf 40" (1 to 500) when buds showed green	Lime-sulfur (1 to 9) + "Black Leaf 40" (1 to 1,000) when buds showed green	Scalecide during dormancy	Scalecide when buds showed green	

TABLE 3

EFFECT OF DIFFERENT TREATMENTS IN APHIS CONTROL EXPERIMENT

Plot No.	TREATMENT	Determination of Infestation, 4/20/1916		Determination of Infestation, 4/28/1916		Remarks
		Stayman Winesap		Twenty Ounce		
		No. of Buds	No. of Lice	No. of Buds	No. of Lice	
1	Lime-sulfur (1 to 9) during dormancy; "Black Leaf 40" (1 to 1,000) + soap (2 lbs. to 50 gal.) when the buds showed green	53	4	60	0	No injury
2	Lime-sulfur (1 to 9) during dormancy, followed by lime-sulfur (1 to 9) + "Black Leaf 40" (1 to 1,000) when buds showed green	57	6	60	1	No injury
3	Lime-sulfur (1 to 9) when buds showed green	54	58	80	8	No injury
4	Lime-sulfur (1 to 9) + "Black Leaf 40" (1 to 500) when the buds showed green	101	6	60	0	No injury
5	Lime-sulfur (1 to 9) + "Black Leaf 40" (1 to 1,000) when the buds showed green	100	53	60	7	No injury
6	Scalecide (1 to 15) during dormancy	75	14	60	2	Badly scorched
7	Scalecide (1 to 15) when the buds showed green	76	5	60	0	Badly scorched; 50 per cent killed

TABLE 4

EFFECT OF DIFFERENT TREATMENTS IN APHIS CONTROL EXPERIMENT

Plot No.	TREATMENT	Determination of Infestation, 4/20/1916		Determination of Infestation, 4/28/1916		Remarks
		Grimes Golden		McIntosh Red		
		No. of Buds	No. of Lice	No. of Buds	No. of Lice	
1	Lime-sulfur (1 to 9) during dormancy; "Black Leaf 40" (1 to 1,000) + soap (2 lbs. to 50 gal.) when buds showed green	68	1	100	0	No injury
2	Lime-sulfur (1 to 9) during dormancy; lime-sulfur (1 to 9) + "Black Leaf 40" (1 to 1,000) when buds showed green	65	4	100	7	No injury
3	Lime-sulfur (1 to 9) when the buds showed green	86	88	100	150	No injury
4	Lime-sulfur (1 to 9) + "Black Leaf 40" (1 to 500) when buds showed green	78	5	100	0	No injury
5	Lime-sulfur (1 to 9) + "Black Leaf 40" (1 to 1,000) when the buds showed green	71	87	100	9	No injury
6	Scalecide (1 to 15) while the buds were dormant	71	8	100	13	Badly scorched
7	Scalecide (1 to 15) when the buds showed green	67	3	100	1	Badly scorched; 50 per cent killed

For the purpose of making a comparison of the results given in the preceding tables easy, table 5 is submitted.

TABLE 5

SUMMARY OF RESULTS IN APHIS CONTROL EXPERIMENT

Plot Numbers	TREATMENT	Total number of buds examined	Total number of aphis found	Number of aphis per 100 buds
1 & 1	Lime-sulfur (1 to 9) during dormancy; "Black Leaf 40" (1 to 1,000) + soap (2 lbs. to 50 gal.) when buds showed green	281	5	1.7
2 & 2	Lime-sulfur (1 to 9) during dormancy; lime-sulfur (1 to 9) + "Black Leaf 40" (1 to 1,000) when buds showed green	282	18	6.3
3 & 3	Lime-sulfur (1 to 9) when the buds showed green	320	304	95.
4 & 4	Lime-sulfur (1 to 9) + "Black Leaf 40" (1 to 500) when buds showed green	339	11	3.2
5 & 5	Lime-sulfur (1 to 9) + "Black Leaf 40" (1 to 1,000) when buds showed green	331	156	47.1
6 & 6	Scalecide (1 to 15) while buds were dormant	306	37	12.
7 & 7	Scalecide (1 to 15) when the buds showed green	303	9	2.9

Note.—Unsprayed trees showed average of 600 aphis per 100 buds. A large block of trees of the same age and variety in the same orchard were sprayed with lime-sulfur (1 to 9) during dormancy. These trees showed an average of 6 aphis to 100 buds.

Lime-sulfur when applied during dormancy seems greatly to reduce the aphis, causing the number to fall from about 600 aphis per 100 buds to 6 aphis to 100 buds. Lime-sulfur when applied in the green-bud stage, after the hatching of the lice, made a much smaller reduction, causing the number to fall from 600 per 100 buds to about 95 per 100 buds.

The combination of winter-strength lime-sulfur and "Black Leaf 40" at the rate of 500 to 1 is more effective than the combination at the rate of 1,000 to 1, as shown by the fact that the former reduces the aphis to 3 individuals to each 100 buds while the latter left 47 lice to each 100 buds.

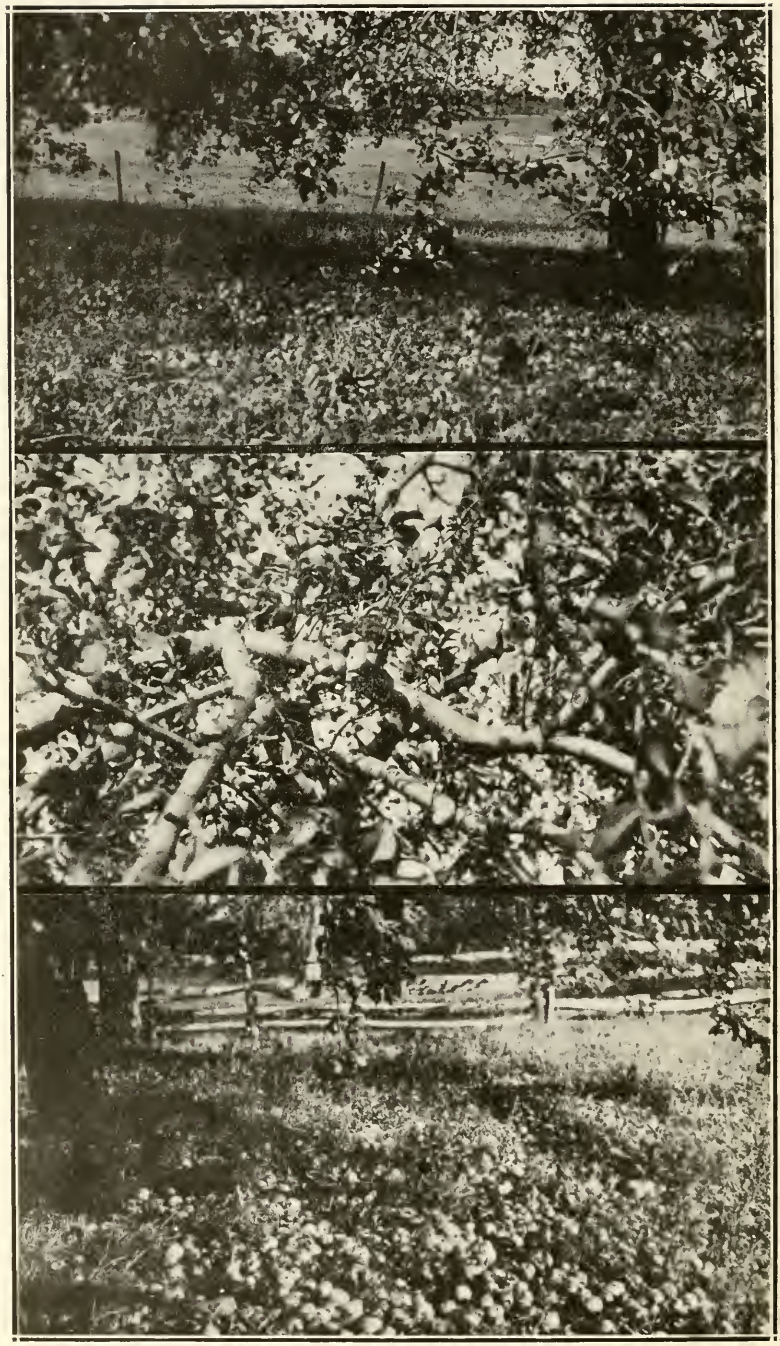

Fig. 4. Trees not properly sprayed for aphis; note small apples and dropped apples

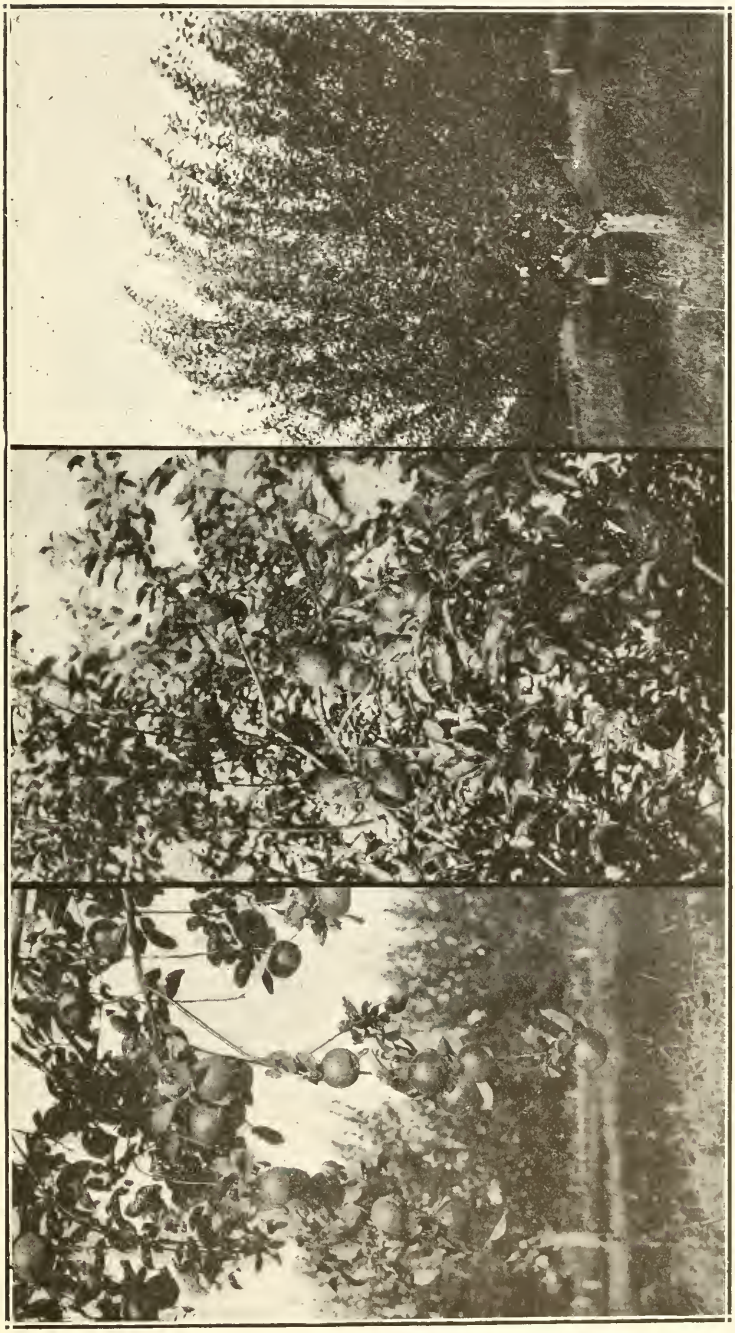

Fig. 5. Trees properly sprayed for aphis: note fine foliage, large fruit, and absence of dropped apples

The application of winter-strength lime-sulfur during dormancy followed by "Black Leaf 40" and soap at the green-bud stage just after the lice had hatched seemed very effective, leaving only 2 lice to each 100 buds.

Scalecide when used during dormancy scorched the buds, and when used during the green-bud stage, after the lice hatched, killed 50 per cent of the buds. In both cases it reduced the number of lice.

Thus it appears that until methods of destroying the egg during dormancy are better developed, the best aphis treatment from the standpoint of labor, safety and efficiency is an application of winter-strength lime-sulfur, to which 40 per cent nicotine has been added at the rate of 1 to 500 at the green-bud stage. Under this system no winter-strength lime-sulfur or soluble-oil treatment is ordinarily required, and the normal labor of orchard procedure increased only slightly.

The one question remaining in the writer's mind after the experiment of 1916 was whether, if the advancement of the trees should compel treatment before hatching, the eggs would not later hatch a damaging brood of lice. The laboratory work of Dr. Peterson in 1917, already mentioned, indicated that the unhatched eggs would be destroyed. Fortunately, there was opportunity to try this out on a field scale.

When the oat aphis appeared on the buds Mr. Barclay sprayed a block of trees with winter-strength lime-sulfur to which "Black Leaf 40" had been added at the rate of 1 to 500. At the same time an adjacent block was sprayed with Scalecide (1 to 15). On the first block practically no aphis appeared thereafter, and trees were almost entirely free from aphis work. On the second block, although only a few living aphis could be found on the afternoon of the day when the spray was applied, colonies of the rosy louse appeared later, curled the foliage and did much damage to the fruit.

No one knows how many aphis per 100 buds may be left unhurt and the crop escape injury. As a matter of fact, the number which may safely be left this year might next year be sufficient to produce large damage, so much depends upon the weather and the natural enemies of the lice. The only safe plan to follow is to kill as many of the lice as possible. *This means the application of the recommended treatment with the utmost thoroughness, for neither lice nor eggs will be destroyed unless they are well covered.*

Assuming that the best practicable treatment for aphis, with our present knowledge, is the application of lime-sulfur and

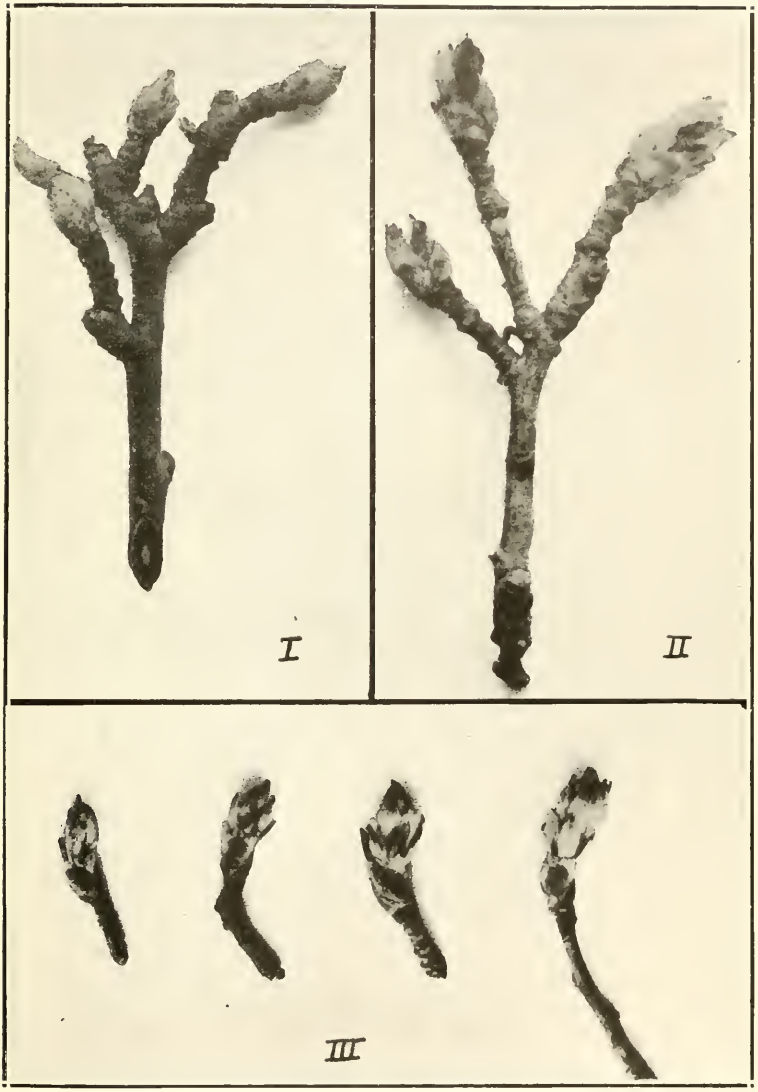

Fig. 6. Stages in bud development. The best time to spray for aphis is the period from *I* to *II; III* illustrates later development

nicotine in such a fashion that all the lice and lice eggs are coated, the question of the time of application becomes exceedingly important. It seems clear from the laboratory and field studies that the green-bud stage is the best, because at that time the maximum number of lice will have hatched and are without shelter, and the unhatched eggs are most susceptible.

The term "green-bud stage" is rather elastic and somewhat difficult to define. When the bud scales first separate at the tip the parts exposed are silvery and only slightly green. The silvery look is due to the presence of a heavy pubescence on the structures exposed. In the course of a very few days this silvery look gives way to a decided green as the edges of the leaves begin to project. Treatment should be completed by the time the latter stage has been reached, for the next stage, which may follow within a single warm day and night, and shows the young leaves projecting from the buds like squirrel ears, is not only liable to be injured by the treatment, but offers shelter to the lice.

CONCLUSIONS

1. Three species of plant lice—green apple aphis, the rosy apple aphis and the oat aphis, especially the first two—attack the foliage and fruit of apple in New Jersey and are capable under favorable conditions of destroying a large percentage of the crop.

2. All species winter over on the water sprouts, twigs, and smaller branches of the apple trees as small shining black oval eggs just large enough to be seen with the naked eye.

3. While it is not possible to forecast an outbreak with certainty, even when the eggs are on the trees, because of the effect of weather and natural enemies, preparations should be made for treatment as a matter of insurance if the eggs are present.

4. Control by destruction of returning migrants and egg-laying individuals in the fall is probably impracticable, because of the number of sprayings that would be necessary.

5. The probability of developing a method of control by destroying the eggs during dormancy seems strong, but in the present state of knowledge it should not be depended on.

6. Control by destroying the aphis after the leaves are pretty well unfolded is likely to prove impracticable because of the shelter which the leaves afford the lice.

7. The most practicable treatment for aphis control is the application of winter-strength lime-sulfur to which 40 per cent

nicotine has been added at the rate of 1 to 500, during the green-bud stage, because the maximum number of lice will be hatched at that time (and will be killed by the nicotine) and the unhatched eggs will be in their most sensitive state (and will be destroyed by the mixture).

8. The green-bud stage is that stage of development which just precedes the escape of the new leaves from the flower buds in such a fashion as to resemble squirrel ears.